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THE NEED FOR TEACHING OF GREEN BIM TECHNOLOGIES IN HIGHER SCHOOL OF 20TH CENTURY

Abstract. Building information modeling (BIM) is a modern and efficient technology in the architectural and construction industry. For the last time Russia is actively involved in the process of implementing BIM. Another trend in constructing corresponds to the concept of sustainable development and is related to sustainable ecological design over "green" standards. Such project should be based on the digital model of the building; in this case it refers to the Green BIM, which allows to perform different calculations for its optimization. For wider dissemination of Green BIM among developers of architectural and construction projects it is necessary to teach it in universities. The department of applied informatics of the Ural State University of Architecture and Art since 2009 has introduced in the educational process BIM-technology and "green" standards in the form of the supplement to traditional courses and practices. This article presents results of Green BIM-technology in a number of diploma projects of graduates of the applied informatics department.

Keywords: BIM, sustainable development, ecological design, "green" architecture, digital model of the building, optimization, teaching process.

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О НЕОБХОДИМОСТИ ОБУЧЕНИЯ GREEN BIM ТЕХНОЛОГИЯМ В ВЫСШЕЙ ШКОЛЕ XXI ВЕКА

Аннотация. Строительное информационное моделирование (BIM) является современной и эффективной технологей в архитектурно-строительной отрасли. В последнее время Россия активно участвует в процессе внедрения BIM. Еще одной тенденцией в строительстве является концепция устойчивого развития, которая связана с экологическим проектированием по «зеленым» стандартам. Такой проект должен быть основан на цифровой модели здания; в данном случае это относится к Green BIM, что позволяет выполнять различные расчеты для его оптимизации. Для более широкого распространения Green BIM среди разработчиков архитектурных и строительных проектов необходимо научить ему в университетах. На кафедре прикладной информатики Уральского государственного университета архитектуры и искусства с 2009 года введены в учебный процесс BIM-технологии и «зеленые» стандарты в виде дополнения к традиционным курсам и практике. В данной статье представлены результаты применения Green BIM-технологии в ряде дипломных проектов выпускников прикладного отдела информатики.

Ключевые слова: BIM, устойчивое развитие, экологическое проектирование, «зеленая» архитектура, цифровая модель здания, оптимизация, процесс обучения.

1. Introduction

Building information modeling (BIM) is a modern and efficient technology in the architectural and construction industry and it is the process of creating and managing information about construction objects at all stages of their life cycle. The technology covers all stakeholders of the project: customer, general designer, general contractor and allows to avoid a large number of errors. Information modeling allows to visualize and calculate a future object with selected materials, to obtain several variants of the cost estimate, to optimize structural part, to remove conflicts of engineering equipment and architectural solutions, and finally to increase the efficiency of the project.

Currently, Russia is actively involved in the process of applying BIM-technology in design and construction practice. In December 29, 2014 the order the Ministry of Construction and Housing and Communal Services of the Russian Federation № 926 "On approval of the phased plan of introduction of BIM in the field of industrial and civil construction" was issued [1]. The Order provides for the selection, expertise and analysis of the "pilot" projects carried out with the use of BIM. It assumes changes in the regulatory, legislative and technical acts, as well as in educational standards.

At the same time, the education system cannot react quickly to such changes in the outside world, systematically BIM-technology is not teaching in universities, so it is necessary to find ways to implement innovative technologies in the educational process for the formation of specialists corresponding to modern requirements.

Another global trend in construction is related to the sustainable design in accordance with "green" standards. The approach supposes the design with optimization of technological, economical factors for environmental security with extensive use of energy-saving technologies and renewable resources, harmonious integration new buildings into the environment. Calculations show that sustainable design not only preserves nature, but is also cost-effective.

The tools for "green" design are the passive and active house technologies [2], using of wind and solar energy, heat pumps, energy efficient controlled lighting, water treatment, solid waste, etc.

There are Russian and international certification schemes for "green" design, such as Green Zoom (Russia), LEED (USA), BREEAM (UK), DGNB (Germany), defining the requirements and criteria for evaluating objects.

The Ministry of Natural Resources and Ecology of the Russian Federation has developed in 2015 the strategy of the Russian Federation of ecological safety for the period up to 2025 and its implementation plan [3]. The document defines the level of environmental safety in the territory, where lives most of the population of Russia at the present time as unsatisfactory. And over the last decade according to experts the situation in this area is not improving.

One of the most important factors for realization of this project is to raise environmental awareness among the young people by means of teaching in universities, particularly in the architectural and construction departments, methods and tools for "green" design.

Corresponding project must be based on the digital model of the building — BIM, it allows to perform multiple calculations for its optimization in terms of efficiency in the further use of the building. In this case, the technology relates to Green BIM [4]. On the basis of building information model it is possible to calculate the energy consumption and to check for compliance with the requirements of energy standards, to simulate the lighting — natural and man-made, to evaluate thermal efficiency, calculate the effect of the use of renewable energy sources, and to estimate the cost of water consumption, CO_2 emissions and other parameters.

This article presents the results of Green BIM-technology in diploma projects of graduates of the department of Applied Informatics of the Ural State University of Architecture and Art.

2. Applying Green BIM in the educational program "Applied Informatics in the Architecture"

2.1. Software to Support Green BIM

For wider dissemination of Green BIM it is necessary to develop educational standards with the support of these innovative technologies for teaching in.

But this process is not fast, so universities must find different forms for rapid introduction of modern technologies in the educational process of architectural and construction and other fields. The most effective way to master new information technologies is the elaboration of graduation projects using the most modern software products and based on the knowledge received during studying.

In the USA a decision to mass promote of BIM was taken in 2002–2003. Almost immediately nearly 2004 American universities began to teach students Revit software, often in place of AutoCAD. This is an example of understanding that education should precede the widespread practical use of technology.

The department of Applied Informatics of the Ural State University of Architecture and Art issues interdisciplinary bachelors in "Applied Informatics" with the profile "Applied Informatics in the Architecture". Since 2009 the department introduces in the educational program elements of Green BIM-technology, including the relevant sections in such disciplines as "Information technologies and control systems in resource saving", "Computer Aided Design", "Urban development environment", "Social and environmental bases of architectural design", "Environmental factors in architecture", educational and industrial practice and others.

We organize the participation of students in scientific and practical workshops of companies which are engaged in the production of new materials and technologies ("Knauf", "Isover", "Teplit", "Teplokrepost", "Velux"), the participation in international competitions ("Saint-Gobain " — designing of Multi-Comfort buildings, Autodesk — "Give a shape to the future"), conferences ("Cities of Russia in XXI century", Ekaterinburg, 2014,"Modern trends in the development of urban systems", Ekaterinburg, 2015), excursions to the enterprises and unique construction objects.

BIM-technology implements by such software systems, as Autodesk Revit, Graphisoft ArchiCAD, Nemetscheck Allplan, Bentley Architecture, Tecla Structure, etc. One of the most widespread platforms in the world, according to the NBS sresearch [5, 6] is Autodesk Revit. Therefore, a special place in training informatics-architects has the study of integrated information technologies based on software package Revit. The studying of this course by students is confirmed by certificates of the Autodesk Company.

The package is intended for architects (Revit Architecture), designers of bearing structures (Revit

Structure) and engineering systems developers (Revit MEP). It provides the possibility of three-dimensional modeling of elements of the building and the flat drawing of design elements, organization of joint work under the project from the concept to production of working drawings and specifications.

Information Modeling is the only technology that can solve such problems optimally. In order to effectively work in it, the company should design library families for engineering systems, architecture and construction, and introduce certain standards and regulations describing the BIM-processes in all aspects of design in BIM: the principle for file names should be defined, places for storage also, fixed area of responsibility for each participant in the process on the basis of the expanded list of project tasks must be declared.

Teamwork over the project of all participants achieves by using Vault Autodesk's or TDMS (CSoft Company) systems for cataloging and integration of objects of architecture and construction. For successful implementation of joint work through shared database it must be a BIM-enterprise standard for reporting results of the work, as well as BIM-manager to coordinate all the work.

In the program Navisworks students acquaint with the principles of 4D and 5D-modeling, which allow to bind the construction process to the timeline and calculate costs, as well as to carry out a comprehensive expertise of architectural objects.

To work with the terrain and infrastructure design AutoCAD Civil 3D software is used.

Development of project concepts is carried out by using the InfraWorks 360 platform to improve the efficiency of data exchange and collaboration.

The visualization of projects is necessary to demonstrate ideas, and presentation tools are needed for better evaluation of project versions. For realistic rendering and animation Autodesk 3DS Max usually is used.

As a new and efficient way for presentation of architectural projects students develop systems of augmented and virtual reality using Unity 3D and Unreal Engine programs.

Energy modeling of buildings is performed in Autodesk Green Building Studio (calculation of wind loads, external flow analysis, energy audits, accounting solar radiation, climate control, calculation of ventilation and air conditioning), the financial model is calculated in Altinvest (economic design validation).

2.2. Examples of Diploma Projects with Green BIM at the Department of Applied Informatics

This section describes some graduation projects of students of the Applied Informatics department accomplished with using of information modeling and certification by "green" standards. In some cases our diploma projects are related to real objects — industrial, public and apartment buildings.

In the thesis work "The use of energy-efficient standard Green Zoom for design of residential buildings" (the student E. A. Kutishenko, the supervisor O. P. Shapovalova, the consultant A. I. Krivonogov, 2015) a conceptual design of the high-rise apartment building was developed, its evaluation with the Russian system of energy efficiency and sustainability Green Zoom for civil and industrial construction projects has been made. The Green Zoom standard was approved and was put into operation in September 2014. On the base of the analysis of certification systems in the field of energy efficiency standards in this work the main factors of space-planning decisions was identified. Actual measures to improve energy efficiency for Russian projects was identified, the possibility of applying of information modeling was investigated. The strategic goal of the Green Zoom standard is to create a favorable living environment with affordable and comfortable housing. The evaluation of buildings according Green Zoom system is carried out at 9 divisions: architectural and planning solutions, the project location and the organization of transport provision, environmental sustainability territory, water efficiency, energy efficiency, reduction of harmful emissions into the atmosphere, environmentally rational choice of building materials and waste control, the ecology of the internal environment of buildings, innovation in design and regional characteristics.

Each section is evaluated separately and provides the maximum number of points. The amount of balls sets the final grade of the building within 30 to 60 points. Developed conceptual design of a 25-storey residential building (Fig. 1) is valued at 53 points, because it contains such solutions as location within walking distance to infrastructure (shops, pharmacy, school, bus stops, etc.), sufficient landscaping and grounds for recreation for children, water efficiency measures. Space-planning solutions of buildings, non-standard glazing and stained glass balconies provide sufficient natural light, saving electricity. In the project environmentally friendly finishing materials, and materials with low or zero emissions into the atmosphere of harmful substances were used. The quality of the internal environment is ensured by a comfortable adjustable lighting, good sound insulation, and fresh air in the apartments by ventilation with heat recovery. The project was implemented in view of the fluctuations in temperature in Ekaterinburg. Complex application of all measures allowed reducing consumption of electricity, heat, water, and saving at least 30% on utility bills. Energy efficiency, thermal efficiency, water efficiency were respectively 10%, 32%, 37%.

In the design process the Green BIM technology was used, that allowed at the earliest stages of design to make decisions that reduce the cost and timing of the project and ensure maximum comfort for living environment. To create a digital model of the building Autodesk Revit was used, the software for visualization was 3DS Max,

Fig. 1. Visualization of the "green" apartment building

energy modeling of the building was carried out in the Autodesk Green Building Studio.

Thesis "Computer-aided design of low-rise residential neighborhood "EcoWorld" on the basis of energy-saving technologies" (the student A. R. Sokolovsky, the supervisor O. P. Shapovalova, the consultant G. B. Zakharova, 2013) is devoted to the research and development of energy-efficient cottage village from wooden structures on the basis of alternative energy sources (Fig. 2) with the use of special computer-aided design systems. This is a real project of company "Teplokrepost", which was attended by our student during the pre-diploma practice. The settlement "EcoWorld" designed in 30 km from Ekaterinburg.

In the center of the settlement is an artificial lake around which along the perimeter of the coastal zone is formed and strengthened the two-stage earthen wall about 3 meters high. Functions of this bulk shaft: fencing, landscaping, creating a favorable microclimate zone, windscreen, hilly ridge for growing ornamental and crop plants. Under the bulk shaft pass pipes for heating and water supply of the residential complex. Exits to the pond from all households pass through arches in the bulk shaft. In the coastal area there are beaches and a gazebo, open part of which is intended for public use for recreational purposes, and in the closed part will be installed the equipment for the operation of utility systems of the residential complex. At the bottom of the pond is paved a collector, through which, by means of the heat pump the heat is taken and transferred for heating and hot water supply of homes.

Thus, the residential complex is provided, on the one hand, the unique landscape features, and on the other — the modern geothermal heating system. It should be noted that the average cost of heating and hot water in houses of the settlement will be much less than with a traditional heating system.

We would also like to point out in this project the proposal for the use of alternative energy sources. The aforementioned heat pump "pumps" accumulated over the warmer months energy from the environment — soil, rock, pond. When they use together, the heat pump and solar panels, there is no need to traverse expensive gas networks that leads to savings money. Another alternative source of energy has been proposed in this project — a system of ventilation with heat recovery, which provides

Fig. 2. The project of energy efficient ecological settlement "EcoWorld"

thermal comfort in the house, does not take place in rooms (is located in the wall), reduces heating costs more than 2 times (coefficient of heat system savings is over 0.9).

The constructive solution of houses meets modern energy-saving requirements. Wooden houses are of frame-panel construction with guards from SIP-panels, with the use of design solutions which exclude thermal bridges in the construction, using effective insulation (styrofoam, ecowool), innovation in design of windows REHAU GENEO with i-glass.

An important component of this diploma project was the selection and justification of corresponding software. After a comparative analysis of CAD systems (Autodesk AutoCAD, Graphisoft ArchiCAD, Autodesk Revit, CadWork) by number of parameters the algorithm of computer-aided design of the settlement by means of CadWork system was chosen. CadWork is leading 3D-CAD/CAM software in the field of wood construction and joinery. In its specialized modules it offers comprehensive software solutions for all stages from planning to production. It affects all aspects of woodworks, any technology of wood construction and interior decoration up to the manufacture of furniture. In addition, CadWork allows processing of any steel, massive or combined structures. From all CadWork system capabilities in this cottage settlement project "EcoWorld" were applied the next: the architecture in the wooden building, construction of prefabricated houses, construction from wooden frame structures, joinery assembly building center.

The following diploma thesis "Information support of collaborative development of architectural projects" (Y. A. Scherbakova, the supervisor A. I. Krivonogov, 2014) is devoted to research capabilities of software for management a collective development of architectural projects at all stages of the life cycle through a shared database. As the object for development the building of experimental workshops of the Central Research Institute of Materials in Ekaterinburg has been selected. The main specialization of the company is research activities in the field of metallurgy and materials, and design and engineering works.

By the beginning of the work on the renovation of the object there was a number of problems: the integrity of the total area by reason of its division into separate sections was broken; the integrity of the operation of power systems, technical and ecological safety on the territory were lost; some sections of the documentation were absent, and the documentation which was available in the archive did not meet modern requirements.

The source data for the work were the technical specification for structural modernization, drawings with technical equipment arrangement plan, taken from the archives and scanned, the results of laser scanning, and digitized plan of the land.

Since the project was quite complex, the team work was organized through the shared database in the common building information model. Participants of the reconstruction project subordinated to BIM-manager, who has focused the work on the coordination of activities and the formation of the ultimate standard for working with BIM. The standards specified who, how and what tools should use in the Revit, which files from the library to take, how open files for viewing, printing, and so on.

The result of this work was an effective project for the reconstruction of the object, rendering of which is shown in Fig. 3. Results of the use of standards: all designers worked by the same rules in the repository; unification of all drawings; effective control and management over the project; improving the overall quality of the project; reducing design time.

Fig. 3. The project of reconstruction of experimental workshops of the Central Research Institute of Materials

Thus, in this article we have shown on examples how the educational program "Applied Informatics in the Architecture" at the Ural State University of Architecture and Art responds to the contemporary requirements of sustainable development for the education of students with knowledge and skills in computer-aided design of energy-efficient environmentally friendly objects.

References

1. *Prikaz Ministerstva stroitel'stva i zhilishchno-kommunal'nogo khoziaistva Rossiiskoi Federatsii* [The order of Ministry of Construction and Housing and Communal Services of the Russian Federation]. Available at: http://www.minstroyrf.ru/upload/iblock/383/prikaz-926pr.pdf (In Russ.).

2. W. Feist. *Gestaltungsgrundlagen Passivhäuser* [The main provisions on the design of passive houses]. Darmstadt, Verlag Das Beispiel, 2000. 143 p. (Russ. ed.: Faist V. *Osnovnye polozheniia po proektirovaniiu passivnykh domov.* Moscow, ACB Publ., 2011. 144 p.).

3. *Proekt Strategii ekologicheskoi bezopasnosti Rossiiskoi Federatsii na period do 2025 goda i plana ee realizatsii* [The strategy of the Russian Federation in ecological safety for the period up to 2025]. Available at: https://www.mnr.gov.ru/regulatory/detail.php?ID=141358&print=Y (In Russ.).

4. Krygiel E., Nies B. *Green BIM: Successful Sustainable Design with Building Information Modeling*. Wiley Publishing, 2008, 268 p.

5. *NBS National BIM Report 2014.* Available at: https://www.thenbs.com/knowledge/nbs-national-bim-report-2014.

6. *NBS National BIM Report 2015.* Available at: https://www.thenbs.com/knowledge/nbs-national-bim-report-2015.